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FURTHER STUDIES ON THE EFFECT OF BOX REINFORCEMENT ON TOP-LOAD COMPRESSION

Project 1108-4 — Report

SUMMARY

A study was made of the effect of reinforcement of boxes by means of paper tape, plastic tape and wax impregnation, supplementing an earlier study of various types of paper tape reinforcement. The following results were obtained with respect to top-load compression performance:

1. There was no marked difference in reinforcement by means of (a) a single layer of tape spanning the vertical edge of a box, and (b) two strips of tape of the same total width as in (a) but overlapped by one inch at the vertical edge of the box. Top-load compression strength at 50% R.H. increased by 16.4 and 19.3% in the two cases, respectively, relative to an unreinforced box. The single layer (i.e., without overlap) would be more appropriate in box manufacturing operations.

2. In a study of the effectiveness of wax reinforcement, the single-face liner was impregnated with wax in a three-inch wide zone centered on the panel scoreline at each vertical edge of the box. Top-load compression strength at 50% R.H. was increased by 16.6% relative to an unreinforced box. Approximately 0.03 lb. of wax was used per box, costing about one cent. Thus, wax reinforcement was comparable to paper tape in performance and cost. A comparison of the two methods at 90% R.H. would be of interest.

3. A comparison of the edgewise compression strength at 90% R.H. of combined board reinforced with five types of plastic tape indicated no improvement with these tapes over kraft paper tape as a means of reinforcing boxes. A limited test of box

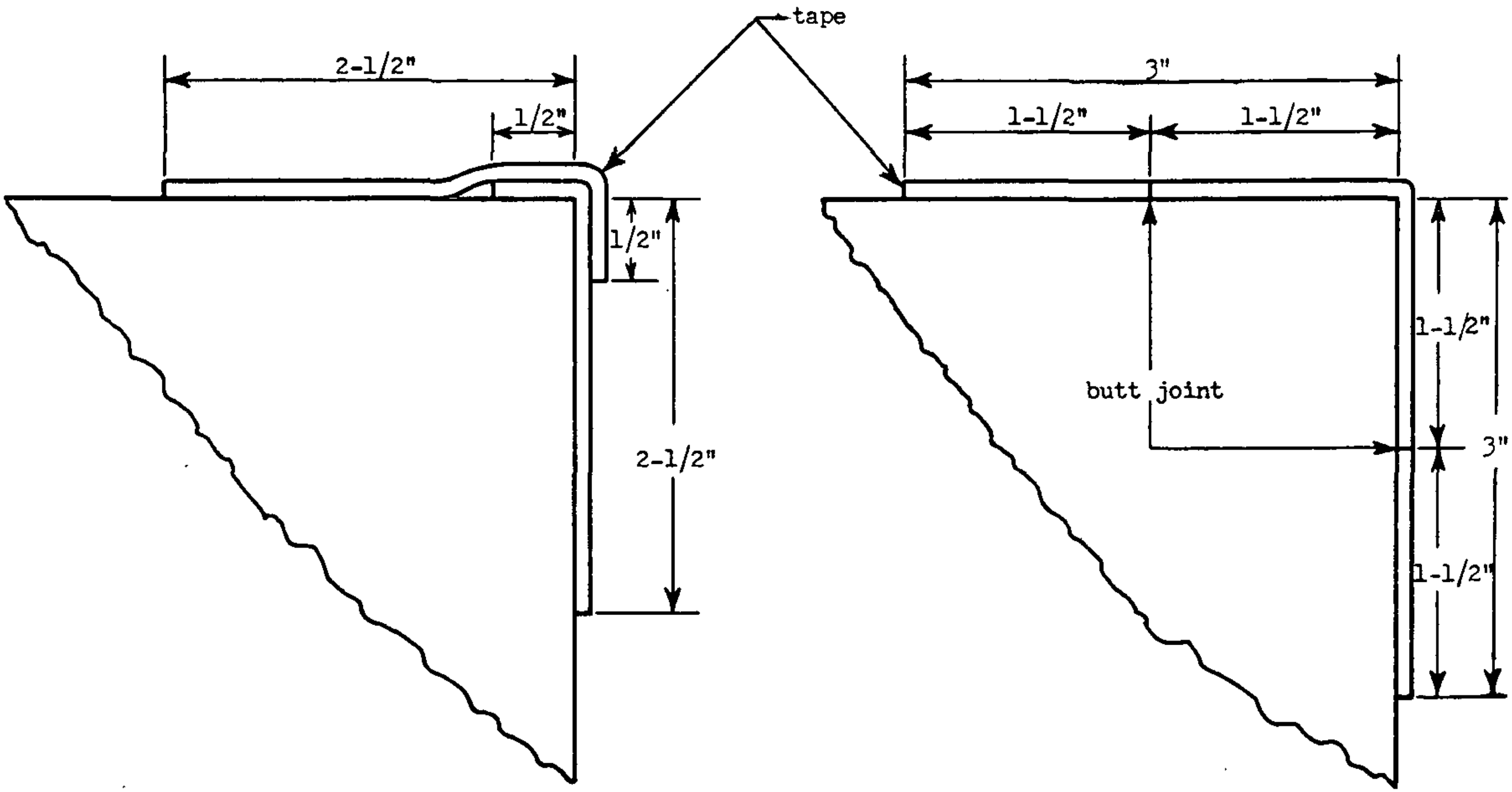
compression strength at high humidity corroborated this result.

A. Paper Tape Reinforcement of the Vertical Edges of a Box.

An earlier study of tape reinforcement of the vertical edges of a box indicated that top-load compression was about 19% higher, on the average, than that of an unreinforced box, when a single thickness of tape was used (1). The results of this preliminary study were achieved by adhering two strips of a three-inch wide kraft gummed tape at each vertical edge. The strips were placed on the two adjacent panels at a given vertical edge and were applied so that two and one-half inches of a strip was on one of the panel faces and one-half inch overlapped the corner onto the adjacent panel (see Fig. 1a). Thus, at the corner there was a double thickness of tape extending for a distance of one-half inch along each of the adjacent panels. The question was raised whether this application of tape to a box would have the same effect as a <u>single</u> strip of tape, six inches wide, applied to the corner. In this latter case, the tape would be placed around the corner with three inches of tape covering each of the adjacent panels with no overlapping (or double thickness) of the tape at the corner (see Fig. 1b). This latter method of tape application to box panels would probably be the easier to adapt to the manufacture of boxes.

This study involves testing the same box sample as used for the work reported in Reference (1) and reinforcing the vertical edges with no overlapping of the tape at the corner. These results are compared with the results of the earlier work.

Inasmuch as a six-inch wide tape was not readily available, a three-inch wide 60-lb. kraft gummed tape was used. Also, since direct comparisons are made with data from Reference (1), the same roll of tape used for that work was used in this study.



(a) Single strip tape reinforcement with overlap at corner.

(b) Single strip tape reinforcement with no overlap at corner.

Figure 1. Top View of Two Methods of Applying Tape to Vertical Edges of Top-Load Boxes

The tape was applied to the vertical edge so that a single strip of tape was placed over the vertical edge with one and one-half inches of width on each adjacent panel, as indicated in Fig. 1b. A second strip of the tape was cut into two 1-1/2-inch wide strips and each of these two narrow strips was placed on the box panels abutting but not overlapping the strip of tape covering the vertical edge. This resulted in a six-inch wide strip of tape covering three inches of each adjacent box panel at the corner with no overlapping of the tape, but with two vertical butt seams, one in each panel one and one-half inches from the corner.

The results obtained from this study are shown in Table I.

TABLE I

TOP-LOAD COMPRESSION STRENGTH OF TAPE REINFORCED BOXES
(200-lb. series A-flute, 16x12x10, 24 No. 2-1/2 can size)

Identification	Number of Specimens	Box Load, lb. Average	Range	Diff., %[a]
Control (no reinforcement)	5	939	885-962	--
Vertical Edge Reinforcement				
A. One layer overlapped (see Fig. 1a)	5	1120	1077-1150	+ 19.3
B. One layer not overlapped (see Fig. 1b)	5	1093	1060-1120	+ 16.4

[a] Based on the strength of unreinforced box.

It may be seen from Table I that both methods of tape application to the vertical edges of a box resulted in substantial increases in the top-load compression strength of the box. The results indicate that a single layer of tape without overlapping gives about the same per cent load increase as did the tape which was overlapped to form a double tape thickness over one-half inch of each adjacent panel--i.e., +16.4% vs. +19.3%. The cost of tape application for both cases is approximately one cent per box since the same amount of tape is used in each case (1).

B. Wax Reinforcement of the Vertical Edges.

Since substantial increases in box load have been experienced by tape reinforcement of the vertical edges of a box, reinforcement of the vertical edges was also tried using a wax treatment. If wax strengthening proved as good as tape, it might have at least four advantages over paper tape: (1) It may be as easily, or perhaps more readily, applied during the manufacturing process of the box; (2) would not suffer from poor adhesion to the liner; (3) it would not detract from the box appearance; and (4) it might prove more beneficial when used at high humidity conditions than would a paper tape.

The same box sample used in the study of tape reinforcement was used in the present experiment. The wax used for vertical edge reinforcement was Carbowax No. 4000 having a melting point of approximately 200° F. The wax was melted, applied to the single-face liner at the vertical edge over the full depth of the box by means of a brush and then was driven into the liner with an infrared heater. Two applications of wax were applied to each of the vertical edges. The wax extended into each panel one and one-half inches, giving a total of three inches of width of wax reinforcement at each vertical edge. The box was conditioned in an atmosphere of 50 ± 2.0% R.H. and 73 ± 3.5° F. after the wax application and prior to testing; testing was done in the conditioning atmosphere.

Table II presents the data obtained in this study as well as from the unreinforced boxes tested in the earlier tape study. The table shows box load, per cent difference, and weight of wax used to treat the boxes.

TABLE II

TOP LOAD COMPRESSION STRENGTH OF WAX REINFORCED BOXES
(200-lb. series A-flute box 16x12x10 - 24 No. 2-1/2 can size)

Identification	Number of Specimens	Box Load, lb. Average	Range	Diff., %[a]	Weight of Wax Applied, lb./box
Control (no reinforcement)	5	939	885-962	--	--
Carbowax No. 4000 reinforcement	5	1095	1034-1245	+ 16.6	0.0316

[a] Based on the strength of unreinforced box.

The data of Table II indicate that wax impregnation in the manner described increased the box compression strength by 16.6%. Reference to the preceeding section of this report reveals that this is virtually the same per cent increase as was obtained with 60-lb. gummed kraft paper tape.

Short columns (cross-machine direction) having the single-face liner impregnated with Carbowax were tested and compared with columns of unreinforced combined board. Both types of column specimens were 2 by 2 inches and were prepared with the standard, wax-reinforced loading edges. The column strength with the single-face liner impregnated was 58.2 lb./in. as compared with 48.2 lb./in. for the unreinforced combined board. Thus, the impregnated board tested 20.7% higher than the plain board, which is compatible with the per cent increase in box load.

Table II shows that approximately 0.03 lb. of wax was used to reinforce a given box (for the five boxes tested, the amount of wax applied ranged from 0.0294 to 0.0342 lb./box). The cost of Carbowax No. 4000 is approximately 30 cents/lb. in carload lots. This means that the cost of reinforcing a single box with

Carbowax No. 4000, exclusive of labor and/or equipment, would be approximately one cent, or the same as the cost of the tape reinforcement.

C. Reinforcement with Plastic Tape for High Humidity Performance.

The object of this study was to determine whether plastic film or filament type of tape (which should be resistant to moisture pick-up) would more adequately reinforce boxes than 60-lb. gummed kraft tape at high humidity.

The program was carried out by first selecting several film and filament tapes. These tapes and the kraft tape were applied to short columns of combined board along with a control sample having no tape reinforcement. The standard 2 by 2-inch wax-edge column was used for this purpose. A two-inch wide strip of tape was applied to the double-face side of the specimen. The material used for this study was the same 200-lb. series, A-flute board used in the other reinforcement studies discussed in the preceding sections of this report. The column specimens were conditioned and tested at 90% R.H.

The plastic tapes used for this work were obtained from the 3-M Company and are identified in Table III:

TABLE III

IDENTIFICATION OF PLASTIC TAPES

Manufacturer's No.	Description[a]
681	Paklon film tape
Y9110	Paklon film tape (heavy duty)
850	Polyester film tape
890	Filament tape
898	Filament tape

[a] All tapes have pressure sensitive adhesive and are three inches in width.

Table IV lists the results obtained in this study, the per cent difference based on the control, and the cost of reinforcement of a 24 No. 2-1/2 can size box.

TABLE IV

CROSS-DIRECTION SHORT COLUMN COMPRESSION RESULTS IN 90% R.H. ATMOSPHERE WITH DIFFERENT TAPE REINFORCEMENTS

Identification	Compression Load, lb./in.[a]	Diff., %[b]	Cost/box, cents[c]
Control (no reinforcement)	16.36	--	--
Kraft tape	19.54	+ 19.4	1
No. 681 tape	18.10	+ 10.6	19
No. Y9110 tape	18.21	+ 11.3	27
No. 850 tape	17.32	+ 5.9	48
No. 890 tape	18.18	+ 11.1	51
No. 898 tape	18.08	+ 10.5	46

[a] Control at 50% R.H. was 48.2 lb./in.
[b] Based on the strength of unreinforced column.
[c] Based on reinforcement with two 3-in. wide strips at each vertical edge of a 24 No. 2-1/2 can size box.

The results shown in Table IV indicate that the plastic tapes did not increase edgewise compression strength as much as did the kraft tape on the same material in an atmosphere of 90% R.H. The kraft tape provided a 19.4% increase in load over the unreinforced combined board strength. The plastic tapes in the high humidity (90% R.H.) showed increases in column load of 5.9 to 11.3% over the unreinforced column results. On a cost basis, figured for a 16x12x10 (24 No. 2-1/2 can size) box, plastic tape would cost 19 to 51 times that of the kraft tape--the latter being about one cent per box. Based on edgewise compression strength, there would be no advantage in using the more expensive tapes for box reinforcement at high humidities.

There was some difficulty in preparing short column specimens with plastic tape because of a tendency for the tape to curl at the ends when treating the loading edges with wax. A check on the column results was afforded by reinforcing several boxes with plastic tape and testing them in top-load compression at 90% R.H. Two boxes from the sample described previously in this report were reinforced along the vertical edges with two 3-inch wide strips of tape No. 681. Two boxes were similarly reinforced with tape No. 898 and two additional boxes were tested without reinforcement. The increase in top-load compression, relative to the unreinforced box, was 1% for tape No. 681 and 7% for tape No. 898. On the basis of these results there is no reason to doubt the conclusions drawn from the short column data.

Both the column specimens and the boxes may have suffered from the presence of occasional air pockets between the tape and the combined board. It is believed that this would be a difficulty in box manufacturing operations also. If the pockets could be entirely prevented, it is possible that the reinforcement may be more effective than in the experiment described here.

In view of the above results, it appears that the plastic (film or filament) tapes used in this study are not as effective in improving box strength as paper tape and would be, in fact, more costly to use.

Future study of box reinforcement under high humidity conditions might well be carried out with wax or resin reinforcement. Nearly the same degree of improvement in box strength was achieved in a 50% R.H. atmosphere with the wax as compared to the kraft tape. Perhaps greater increases in box load would be experienced at 90% R.H. with thermoplastics than with paper tape since the thermoplastics should be more resistant to moisture.

Literature Cited

1. The Institute of Paper Chemistry. Effect of reinforcement on top-load box compression. A preliminary report to the Technical Committee of Fourdrinier Kraft Board Institute, In., January 21, 1964.